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*Quantum Simulations of Many-Body Systems with Ultra-Cold  
Atoms*

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**20090410043**

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## Abstract

The present project addressed theoretical issues that are crucial for the experimental simulations of strongly correlated electron systems using cold atoms samples. The work focused on the two main avenues:

- 1) Preparation of strongly correlated quantum phases, such as anti-ferromagnetic insulating or d-wave paired states of fermions in optical lattices. Approaches studied included the dynamic changes of systems parameters, cooling, or their combinations. The emphasis was on developing procedures that utilized realistic resources to reach relevant phases with high accuracy for experimentally available system parameters (such as temperature, interaction strength, and lifetimes of condensates). Systematic figures of merits for the successful preparation of desired quantum phases were developed as a part of this effort.
- 2) Detection of many body phases. Experimental tools commonly used in condensed matter systems, such as transport measurements, or scattering experiments are not available for cold atoms. Hence, we developed new approaches for analyzing correlated many body phases that rely on detection tools appropriate for atomic samples, such as interference or imaging after free expansion in time of flight experiments. Key approaches included the analysis of quantum noise intrinsic to any measurement in cold atoms samples and the dynamical response of strongly correlated systems.

Our emphasis was on two specific areas: exotic superconductivity and quantum magnetic systems. The work paved the way for experimental quantum simulations of these systems.

## Technical Report

We proposed a controlled method to create and detect d-wave superfluidity with ultracold fermionic atoms loaded in two-dimensional optical superlattices. Our scheme consisted of preparing an array of nearest neighbor coupled square plaquettes or “superplaquettes” and using them as building blocks to construct a d-wave superfluid state. We described how to use the coherent dynamical evolution in such a system to experimentally probe the pairing mechanism. We also derived the zero temperature phase diagram of the fermions in a checkerboard lattice (many weakly coupled plaquettes) and show that by tuning the inter-plaquette tunneling spin dependently or varying the filling factor one can drive the system into a d-wave superfluid phase or a Cooper pair density wave phase. We discussed the use of noise correlation measurements to experimentally probe these phases. [cond.mat/0806.0166v1,submitted to Nature Physics (2008)]

We suggested and analyzed a novel technique for efficient and robust creation of dense ultracold molecular ensembles in their ground rovibrational state. In our approach a molecule was brought to the ground state through a series of intermediate vibrational states via a multi-state chain wise Stimulated Raman Adiabatic Passage (c-STIRAP) technique. We studied the influence of the intermediate states decay on the transfer process and suggested an approach that minimizes the population of these states, resulting in maximal transfer efficiency. As an example, we analyzed the formation of  $^{87}\text{Rb}_2$  starting from an initial Feshbach molecular state and taking into account major decay mechanisms due to inelastic atom-molecule and molecule-molecule collisions. Numerical analysis suggested a transfer efficiency  $> 90\%$ , even in the presence of strong collisional relaxation as are present in a high density atomic gas.[Physical Review A 78, 021402 (2008)]

We proposed and analyzed a technique that allows the suppression of inelastic collisions and simultaneously enhances elastic interactions between cold polar molecules. The main idea was to cancel the leading dipole-dipole interaction with a suitable combination of static electric and microwave fields in such a way that the remaining van-der-Waals-type potential forms a three-dimensional repulsive shield. We analyzed the elastic and inelastic scattering cross sections relevant for evaporative cooling of polar molecules and discussed the prospect for the creation of crystalline structures.[ Phys. Rev. Lett. 101, 073201(2008)]

We discussed a method to achieve decoherence resistant entanglement generation in two level spin systems governed by gapped and multi-degenerate Hamiltonians. In such systems, while the large number of degrees of freedom in the ground state levels allows to create various quantum superpositions, the energy gap prevents decoherence. We

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applied the protected evolution to achieve decoherence resistant generation of many particle GHZ states and showed it can significantly increase the sensitivity in frequency spectroscopy. We discussed how to engineer the desired many-body protected manifold in two specific physical systems, trapped ions and neutral atoms in optical lattices, and presented simple expressions for the fidelity of GHZ generation under non-ideal conditions. [Phys.Rev.A 77 052305 (2008)]

We reported on the observation of the phase dynamics of interacting one-dimensional ultracold bosonic gases with two internal degrees of freedom. By controlling the non-linear atomic interactions close to a Feshbach resonance we were able to induce a phase diffusive many-body spin dynamics. We monitored this dynamical evolution by Ramsey interferometry, supplemented by a novel, many-body echo technique. We found that the time evolution of the system is well described by a Luttinger liquid initially prepared in a multimode squeezed state. Our approach allowed us to probe the non-equilibrium evolution of one-dimensional many-body quantum systems.. [Phys.Rev.Lett. 100, 140401 (2008)]

We suggested a new method for quantum optical control with nanoscale resolution. Our method allowed for coherent far-field manipulation of individual quantum systems with spatial selectivity that is not limited by the wavelength of radiation and can, in principle, approach a few nanometers. The selectivity was enabled by the nonlinear atomic response, under the conditions of Electromagnetically Induced Transparency, to a control beam with intensity vanishing at a certain location. Practical performance of this technique and its potential applications to quantum information science with cold atoms, ions, and solid-state qubits were discussed. [Phys.Rev.Lett. 100 09305 (2008)]

Strongly correlated quantum systems can exhibit exotic behavior called topological order which is characterized by non-local correlations that depend on the system topology. Such systems can exhibit remarkable phenomena such as quasi-particles with anyonic statistics and have been proposed as candidates for naturally error-free quantum computation. However, anyons have never been observed in nature directly. Here, we described how to unambiguously detect and characterize such states in recently proposed spin-lattice realizations using ultracold atoms or molecules trapped in an optical lattice. We proposed an experimentally feasible technique to access non-local degrees of freedom by carrying out global operations on trapped spins mediated by an optical cavity mode. We showed how to reliably read and write topologically protected quantum memory using an atomic or photonic qubit. Furthermore, our technique can be used to probe statistics and dynamics of anyonic excitations.[Nature Physics 4, 482-488 (2008)]

We proposed a method for controllable generation of non-local entangled pairs using spinor atoms loaded in an optical superlattice. Our scheme iteratively increased the distance between entangled atoms by controlling the coupling between the double wells. When implemented in a finite linear chain of  $2N$  atoms, it created a triplet valence bond state with large persistency of entanglement (of the order of  $N$ ). We also studied the non-equilibrium dynamics of the one-dimensional ferromagnetic Heisenberg Hamiltonian and showed that the time evolution of a state of decoupled triplets on each double well leads

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to the formation of a highly entangled state where short-distance anti-ferromagnetic correlations coexist with longer-distance ferromagnetic ones. We presented methods for detection and characterization of the various dynamically generated states. These ideas are a step forward towards the use of atoms trapped by light as quantum information processors and quantum simulators. [Phys. Rev. A 78, 012330 (2008)]

Understanding strongly correlated quantum systems is a central problem in many areas of physics. The collective behavior of interacting particles gives rise to diverse fundamental phenomena such as confinement in quantum chromodynamics, phase transitions, and electron fractionalization in the quantum Hall regime. While such systems typically involve massive particles, optical photons can also interact with each other in a nonlinear medium. In practice, however, such interactions are often very weak. Here we described a novel technique that allows the creation of a strongly correlated quantum gas of photons using one-dimensional optical systems with tight field confinement and coherent photon trapping techniques. The confinement enables the generation of large, tunable optical nonlinearities via the interaction of photons with a nearby cold atomic gas. In its extreme, we showed that a quantum light field can undergo fermionization in such one-dimensional media, which can be probed via standard photon correlation measurements. [Nature Physics 4 884-889 (2008)]

We proposed and analyzed a scheme that makes use of interactions between spins to protect certain correlated many-body states from decoherence. The method exploited the finite energy gap of properly designed Hamiltonians to generate a manifold insensitive to local noise fluctuations. We applied the scheme to achieve decoherence-resistant generation of many particle GHZ states and showed that it can improve the sensitivity in precision spectroscopy with trapped ions. Finally we also showed that cold atoms in optical lattices interacting via short range interactions can be utilized to engineer the required long range interactions for a robust generation of entangled states.

[cond.mat/073108, submitted to Phys. Review A (2007)]

Quantum mechanical superexchange interactions form the basis of quantum magnetism in strongly correlated electronic media. We reported on the direct measurement of superexchange interactions with ultracold atoms in optical lattices. After preparing a spin-mixture of ultracold atoms in an anti-ferromagnetically ordered state, we measured coherent superexchange-mediated spin dynamics with coupling energies from 5 hertz up to 1 kilohertz. By dynamically modifying the potential bias between neighboring lattice sites, the magnitude and sign of the superexchange interaction can be controlled, thus allowing the system to be switched between anti-ferromagnetic and ferromagnetic spin interactions. We compared our findings to predictions of a two-site Bose-Hubbard model and found very good agreement, but were also able to identify corrections that can be explained by the inclusion of direct nearest-neighbor interactions. [Science, 319, 5861, 295-299 (2008)]

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We studied Chern numbers to characterize the ground state of strongly interacting systems on a lattice. This method allowed us to perform a numerical characterization of bosonic fractional quantum Hall (FQH) states on a lattice where the conventional overlap calculation with the known continuum case such as the Laughlin state, breaks down due to the lattice structure or dipole-dipole interaction. The non-vanishing Chern number indicated the existence of a topological order in the degenerate ground-state manifold. [Europhys.Lett, 81, 10005 (2008)]

We studied the problem of rapid change of the interaction parameter (quench) in a many-body low-dimensional system. It was shown that, measuring the correlation functions after the quench, the information about a spectrum of collective excitations in a system can be obtained. This observation was supported by analysis of several integrable models and we argued that it is valid for nonintegrable models as well. Our conclusions were supplemented by performing exact numerical simulations on finite systems. We proposed that measuring the power spectrum in a dynamically split 1D Bose-Einstein condensate into two coupled condensates can be used as an experimental test of our predictions. [Phys.Rev.Lett, 99, 200404 (2007)]

We proposed a method to perform precision measurements of the interaction parameters in systems of  $N$  ultracold spin 1/2 atoms. The spectroscopy was realized by first creating a coherent spin superposition of the two relevant internal states of each atom and then letting the atoms evolve under a squeezing Hamiltonian. The nonlinear nature of the Hamiltonian decreases the fundamental limit imposed by the Heisenberg uncertainty principle to  $N-2$ , a factor of  $N$  smaller than the fundamental limit achievable with non-interacting atoms. We studied the effect of decoherence and showed that, even with decoherence, entangled states can outperform the signal to noise limit of nonentangled states. We presented two possible experimental implementations of the method using Bose-Einstein spinor condensates and fermionic atoms loaded in optical lattices and discussed their advantages and disadvantages. [Phys.Rev.A, 76, 053617 (2007)]

We analyzed a recently proposed method to create fractional quantum Hall (FQH) states of atoms confined in optical lattices [A. Sørensen et al., Phys. Rev. Lett. 94, 086803 (2005)]. Extending the previous work, we investigated conditions under which the FQH effect can be achieved for bosons on a lattice with an effective magnetic field and finite on-site interaction. Furthermore, we characterized the ground state in such systems by calculating Chern numbers which can provide direct signatures of topological order and explored regimes where the characterization in terms of wave-function overlap fails. We also discussed various issues which are relevant for the practical realization of such FQH states with ultracold atoms in an optical lattice, including the presence of a long-range dipole interaction which can improve the energy gap and stabilize the ground state. We also investigated a detection technique based on Bragg spectroscopy to probe these systems in an experimental realization. [Phys.Rev.A, 76, 023613 (2007)]

We described a novel approach to prepare, detect, and characterize magnetic quantum phases in ultracold spinor atoms loaded in optical superlattices. Our technique made use of singlet-triplet spin manipulations in an array of isolated double-well potentials in

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analogy to recently demonstrated control in quantum dots. We also discussed the many-body singlet-triplet spin dynamics arising from coherent coupling between nearest neighbor double wells and derive an effective description for such systems. We used it to study the generation of complex magnetic states by adiabatic and nonequilibrium dynamics. [Phys.Rev.Lett, 99, 140601 (2007)]

We reported on a study of the dynamics of decoherence of a matter-wave interferometer, consisting of a pair of low-dimensional cold atom condensates at finite temperature. We identified two distinct regimes in the time dependence of the coherence factor of the interferometer: quantum and classical. Explicit analytical results were obtained in both regimes. In particular, in the two-dimensional case in the classical (long time) regime, we found that the dynamics of decoherence is universal, exhibiting a power-law decay with an exponent, proportional to the ratio of the temperature to the Kosterlitz-Thouless temperature of a single 2D condensate. In the one-dimensional case in the classical regime we found a universal non-analytic time dependence of decoherence, which is a consequence of the non-hydrodynamic nature of damping in 1D liquids. [Phys.Rev.Lett, 98, 200404 (2007)]

We discussed techniques to tune and shape the long-range part of the interaction potentials in quantum gases of bosonic polar molecules by dressing rotational excitations with static and microwave fields. This provided a novel tool towards engineering strongly correlated quantum phases in combination with low-dimensional trapping geometries. As an illustration, we discussed the 2D superfluid-crystal quantum phase transition for polar molecules interacting via an electric-field-induced dipole-dipole potential. [Phys.Rev.Lett, 98, 060404 (2007)]

We developed techniques to tune and shape the long-range part of the interaction potentials in quantum gases of bosonic polar molecules by dressing rotational excitations with static and microwave fields. This provides a novel tool towards engineering strongly correlated quantum phases in combination with low-dimensional trapping geometries. As an illustration, we analyzed the 2D superfluid-crystal quantum phase transition for polar molecules interacting via an electric-field-induced dipole-dipole potential. [Phys.Rev.Lett. 98, 060404 (2007)]

We studied polar molecules in a stack of strongly confined pancake traps. When dipolar moments point perpendicular to the planes of the traps and are sufficiently strong, the system is stable against collapse but attractive interaction between molecules in different layers leads to the formation of extended chains of molecules, analogously to the chaining phenomenon in classical rheological electro- and magnetofluids. We analyzed properties of the resulting quantum liquid of dipolar chains and showed that only the longest chains undergo Bose-Einstein condensation with a strongly reduced condensation temperature. We discussed several experimental methods for studying chains of dipolar molecules. [Phys.Rev.Lett. 97, 180413 (2006)]

We considered spin-polarized mixtures of cold fermionic atoms on the BEC side of the Feshbach resonance. We demonstrated that a strongly anisotropic confining potential can

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give rise to a double peak structure in the axial distribution of the density difference and a polarization dependent aspect ratio of the minority species. We pointed out that both phenomena are not necessarily related to phase separation and may appear as a result of the breakdown of the local density approximation. We considered the implications of our findings for the unitary regime. [Phys.Rev.A 74, 53626 (2007)]

We considered bosonic dipolar molecules in an optical lattice prepared in a mixture of different rotational states. The  $1/r^3$  interaction between molecules for this system is produced by exchanging a quantum of angular momentum between two molecules. We showed that the Mott states of such systems have a large variety of non-trivial spin orderings including a state with ordering wave vector that can be changed by tilting the lattice. As the Mott insulating phase is melted, we also described several exotic superfluid phases that will occur. [Phys.Rev.Lett. 96, 190401 (2006)]

We analyzed the use of quantum noise for characterizing many-body states of spin systems realized with ultracold atomic systems. These systems offer a wealth of experimental techniques for realizing strongly interacting many-body states in a regime with a large but not macroscopic number of atoms where fluctuations of an observable such as the magnetization are discernable compared to the mean value. The full distribution function is experimentally relevant and encodes high order correlation functions that may distinguish various many-body states. We apply quantum noise analysis to the Ising model in a transverse field and find a distinctive even versus odd splitting in the distribution function for the transverse magnetization that distinguishes between the ordered, critical, and disordered phases. We also discussed experimental issues relevant for applying quantum noise analysis for general spin systems and the specific results obtained for the Ising model. [New Journal of Physics 9, 7 (2007)]

## Personnel

### **Supported Personnel**

Professor Mikhail Lukin  
Profesor Eugene Demler  
Dr. Vladimir Gritsev

### **Associated Personnel**

Dr. Ryan Barnett  
Dr. Addilet Imambekov  
Dr. Ana Maria Rey  
Dr. Daw-Wei Wang  
Mohammad Hafezi  
Liang Jiang  
Ari Turner  
Alexei Gorshkov

# Presentations at Meetings, Conferences, Seminars

## Mikhail Lukin

1. Physics Colloquium at Humboldt University, Berlin, Germany January 2009
2. Invited talk at Cortina Conference, Italy, January 2009
3. Invited talk at IBM Thomas J. Watson Research Center, NY, September 2008
4. Invited talk at Laser Physics Workshop 2008, Trondheim Norway, July 2008
5. Invited talk at JQI (Joint Quantum Institute), University of Maryland, March 2008
6. Snowbird Conference, Physics of Quantum Electronics, Utah, January 2008
7. 26<sup>th</sup> Annual Jerusalem Winter School in Theoretical Physics, Hebrew University, Israel, January 2008
8. Invited talk at Stuttgart Institute of Physics, Stuttgart, Germany, December 2007
9. Invited talk at the Darpa Slow Light Review, Washington DC, November 2007
10. Invited talk at the QIPC 2007 International Conference on Quantum Information Processing and Communication, Barcelona, Spain, October 2007
11. Physics Colloquium at Stanford University, October 2007
12. Invited talk at the MURI Center for Photonic Quantum Information Systems Annual Meeting, Stanford University, CA, October 2007
13. Invited talk at the Quantum Metrology MURI Review, Washington, DC, October 2007
14. Invited talk at the Packard Fellows 19<sup>th</sup> Annual Meeting, Monterey, CA September 2007
15. Lecture Series at the School on Quantum Information Studies, Bad Honnef, Germany, September 2007
16. Invited talk at the NSF Workshop on Quantum Information Processing and Nano-Scale Systems, Arlington, VA, September 2007
17. Invited talk at the Coherent Control of Ultra-Cold Molecular Processes, University of British Columbia, Vancouver, August 2007
18. Invited talk at the Gordon Research Conference, Quantum Control of Light and Matter, Salve Regina University, Newport, RI, August 2007
19. Invited talk at "Coherent Control of Ultracold Molecular Processes," University of Vancouver, July 2007
20. Invited talk at Workshop on N-V Center in Diamond for Quantum Computing, Australia, July 2007 (teleconference presentation)
21. Plenary talk at Third International Conference "Frontiers of Nonlinear Physics" Nizhny Novgorod, Russia, July 2007
22. Invited talk at Institute Henri Poincare, Centre Emile Borel, Paris, "Recent Progress in the Studies of Quantum Gases" June 2007
23. Invited talk at Niels Bohr International Academy workshop on Solid state quantum information systems, June-July 2007
24. Invited talk at DAMOP 2007, Calgary, Canada, June 2007
25. "Quantum Nanoscience with Spins," Monterey, CA, June 2007
26. CQO9 and ICQI, University of Rochester, June 2007
27. Invited talk at Quantum Molecular and High Performance Modeling and Simulation for Devices and Systems (QMHP), Washington DC, April 2007

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28. Invited talk at Gordon Research Conference, Il Ciocco, Italy, April 2007
29. KITP Seminar at the University of California at Santa Barbara, April 2007
30. Invited talk at International Workshop on Measurement-based Quantum Computing, Oxford University, Oxford, England, March 2007
31. Physics Colloquium at UC San Diego, La Jolla, CA, March 2007
32. Colloquium at the Institute for Quantum Computing, University of Waterloo, March 2007
33. Focus Center Seminar, University of Michigan, February 2007
34. Lecture Series at QUROPE Winter School on Quantum Information, Obergurgl, Austria, February 2007
35. Invited talk at Physics of Quantum Electronics, Salt Lake City, January 2007
36. Quantum Information Seminar at Rutgers University, Piscataway, NJ, January 2007
29. Stanford University, Stanford Photonics Research Center Workshop, September 2006
30. Penn State Colloquium, College Station, PA, September 2006
31. Optical Society of America, Washington DC, July 2006
32. MURI Review Presentation on Precision Measurement and Gap Protection, by Dr. Ana Maria Rey, Stanford University, Stanford, CA, June 2006
33. 366. WE-Heraeus seminar, "Qubits and Macroscopic Quantum Coherence: From Superconducting Devices to Ultracold Gases," Bad Honnef, Germany, May 2006
34. ICQO 2006: XI International Conference on Quantum Optics, Minsk, Belarus, May 2006
35. Topological Phases and Quantum Computation, Kavli Institute for Theoretical Physics, University of California at Santa Barbara, CA, May 2006

**Eugene Demler**

1. Colloquium at Stanford University, December 5, 2006. Strongly correlated systems: from electronic materials to cold atoms.
2. Condensed Matter seminar at the University of British Columbia, December 7, 2006. Quantum noise in systems of cold atoms.
3. Condensed Matter seminar at Brown University, February 1, 2007. Strongly correlated systems: from electronic materials to cold atoms.
4. Colloquium at Boston University, February 6, 2007. Strongly correlated systems: from electronic materials to cold atoms.
5. Inaugural symposium of the Joint Quantum Institute, University of Maryland, March 25-27, 2007. Quantum coherence and interactions in many body systems.
6. Symposium on Condensed Matter Phases in Ultracold Atoms. German Physical Society Meeting, Regensburg, March 29, 2007. Probing interacting systems of cold atoms using interference experiments.

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7. Hamburg, Germany, April 2-3 2007. Colloquium: Quantum coherence and interactions in many body systems. Seminar: Spinor condensates beyond mean-field.
8. Colloquium at the Atomic Institute of the Austrian Universities, Vienna, Austria, April 4, 2007. Probing interacting systems of cold atoms using interference experiments.
9. Symposium "50 Years of the BCS Theory of Superconductivity", Brown University, Providence, RI, April 13, 2007. Strongly correlated quantum systems: from electronic materials to cold atoms.
10. Conference "Strongly Correlated Phases in Condensed Matter and Degenerate Atomic Systems", KITP, University of California at Santa Barbara, April 24, 2007. Strongly correlated many-body systems: from electronic materials to cold atoms to photons.
11. The Ninth Rochester Conference on Coherence and Quantum Optics, University of Rochester Campus Rochester, New York, USA, June 13-15, 2007. Fundamental noise in matter interferometers.
12. International trimester on quantum gases, Institut Henri Poincare, Paris, France. April 23 - July 20, 2007. Non-equilibrium quantum dynamics of many-body systems of cold atoms.
13. Conference "Recent progress in the studies of quantum gases: theory and experiments", Institut Henri Poincare, Paris, France. June 27 - June 29, 2007. Multicomponent BEC: from spinor condensates to chains. of polar molecules
14. Workshop on Low-D Quantum Condensed Matter, Korteweg-de Vries Institute, University of Amsterdam, The Netherlands. July 2-7, 2007. From interference experiments with cold atoms to Sine-Gordon models to statistical properties of random surfaces.
15. Workshop "Dynamics and Thermodynamics of systems with long range interactions". Assisi, Italy; 4-8 July 2007. From interference experiments with cold atoms to Sine-Gordon models to statistical properties of random surfaces.
16. Workshop "Coherent control of ultracold molecular processes". Peter Wall Institute for Advanced Study, University of British Columbia, Vancouver, Canada. August 1-4, 2007. Cold atoms and molecules beyond BEC.
17. Summer School on "Novel Quantum Phases and Non-equilibrium Phenomena in Cold Atomic Gases". Trieste, Italy. August 27-September 7. Strongly correlated many-body systems: from electronic materials to cold atoms to photons.
18. BEC 2007 conference. Sant Feliu, Spain. 15-20 September, 2007. Muticompoment systems of ultracold atoms
19. DARPA gBECi and OLE/MURI Review Meeting. Newport, Rhode Island. October 9-12, 2007.
20. Colloquium in Michigan State University, Lansing, Michigan, November 2007. Quantum noise studies of ultracold atoms
21. J. Gutenberg lectures. November 13-17, 2006. Kaiserslautern and Mainz,Germany.
22. CIAR Quantum Materials meeting. October 18-21, 2006. Vancouver, Canada. Strongly correlated quantum systems: from electronic materials to cold atoms to photons

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23. Condensed Matter seminar at Ohio State University, October 9, 2006. Quantum noise in systems of cold atoms
24. ICAP 2006 - 20th International Conference on Atomic Physics. July 16-21, 2006. Innsbruck, Austria. Interference of fluctuating condensates
25. The 8th International Conference on Materials and Mechanisms of Superconductivity (M2S-HTSC VIII). July 9-14, 2006. Dresden, Germany. Strongly correlated systems of cold atoms
26. International School of Physics "Enrico Fermi" - COURSE CLXIV ULTRA-COLD FERMI GASES. June 20-30, 2006. Varenna (Lake Como), Italy. Measuring correlation functions in interacting systems of cold atoms
27. Advanced Research Workshop "Meso-06". Mesoscopic and strongly correlated electron systems - 4. Nanoscale superconductivity and magnetism. June 14-19, 2006. Chernogolovka, Russia. Strongly correlated systems of cold atoms
36. School on Scalable Quantum Information Processing and Computing, June 11-24, 2006. Benasque, Spain. Simulations of strongly correlated electron systems using cold atoms
37. International workshop on "Correlated and Many-Body Phenomena in Dipolar Systems", May 29, 2006. MPIPKS Dresden, Germany. Polar molecules in optical lattices

## Publication List

Mikhail Lukin & Eugene Demler

1. A.M. Rey, R. Sansarma, S. Foelling, M. Greiner, E. Demler, M.D. Lukin, "Preparation and detection of d-wave superfluidity in two dimensional optical superlattices," cond.mat/0806.0166v1, submitted to Nature Physics (2008)
2. Elena Kuznetsova, Philippe Pellegrini, Robin Cote, M.D. Lukin, S.F. Yelin, "Formation of deeply bound molecules via chain wise adiabatic passage," Physical Review A **78**, 021402 (2008)
3. A.V. Gorshkov, P.Rabl, G. Pupillo, A. Micheli, P. Zoller, M.D. Lukin, H.P. Büchler, "Suppression of inelastic collisions between polar molecules with a repulsive shield," Phys. Rev. Lett. **101**, 073201(2008).
4. A.M. Rey, L. Jiang, M. Fleischhauer, E. Demler, M.D. Lukin, "Many-body protected entanglement generation in interacting spin systems," Phys.Rev.A, 052305 (2008)
5. AA. Widera, S. Trotsky, P. Cheinet, S. Foelling, F. Gerbier, I. Bloch, V. Gritsev, M.D. Lukin, E. Demler, "Quantum spin dynamics of squeezed Luttinger liquids in two-component atomic gases," Phys.Rev.Lett. **100**, 140401 (2008)
6. A. Tokuno, M. Oshikawa, E. Demler, Dynamics of one-dimensional Bose liquids: Andreev-like reflection at Y-junctions and absence of the Aharonov-Bohm effect, Phys. Rev. Lett. 100:140402 (2008)
7. A.V. Gorshkov, L. Jiang, M. Greiner, P.Zoller, M.D. Lukin, "Coherent Quantum Optical Control with Sub-wavelength Resolution," Phys.Rev.Lett, 100, 093005 (2008)
8. L. Jiang, G.K. Brennen, A.V. Gorshkov, K. Hammerer, M. Hafezi, E. Demler, M.D. Lukin, P. Zoller, "Anyonic interferometry and protected memories in atomic spin lattices," Nature Physics 4, 482-488 (2008)
9. P. Barmettler, A. M. Rey, E. Demler, M.D. Lukin, I. Bloch, V. Gritsev, "Quantum many-body dynamics of coupled double well superlattices," Phys. Rev. A **78**, 012330 (2008)
10. D.E. Chang, V. Gritsev , G. Morigi, V. Vuletic, M.D. Lukin, E.A. Demler, "Crystallization of strongly interacting photons in a nonlinear optical fiber," Nature Physics 4 884-889 (2008)
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